‘Nonblocking’ a.c. preamplifier for tip recording from insect taste hairs

Maes, F.W.

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Technical note

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Introduction

BY MEANS of the technique of HODGSON *et al.* (1955), action potentials can be recorded from an insect taste hair via the stimulus solution applied to its tip. A peculiarity of this technique is that the recording circuit is not completed until the stimulus is applied to the tip of the hair. This instant is signalled by a large and troublesome artefact which frequently blocks a preamplifier for 100 ms. However, in blowflies, the first part of the taste cell response is functionally important, as the latency of the first action potential can be as short as 2 ms (MAES and DEN OTTER, 1976), and proboscis extension can start after 20 to 30 ms (DEN OTTER, 1968). Several methods were tried out to make the beginning of the response accessible for analysis: insertion of a small coupling capacitor between the active electrode and the preamplifier input, short-circuiting of the input until the instant of stimulation, the use of a bandpass filter (HODGSON and ROEDER, 1956); the use of a bucking potential (WOLBARSHT, 1958); and side-wall recording (MORITA, 1959). None of these methods, however, appeared to be capable of yielding responses from and including the first spike in a reliable and comfortable fashion.

In this note, the problem of recording the first part of the taste-cell response is reconsidered, and the design of a 'non-blocking' a.c. preamplifier is presented. Results obtained with this preamplifier have already been published (MAES and DEN OTTER, 1976).

Reconsideration of the blocking problem

When the recording circuit is open, the input voltage V_1 of a preamplifier is determined by the input resistance and the input bias current of the amplifier. Often, V_1 has 'run away' to (plus or minus) the supply voltage. After the recording circuit has been closed, the input voltage approximates the direct voltage difference V_2 between the recording electrodes, which may result from biogenic, electrode, and concentration potentials; V_2 may amount to a few hundred millivolts.

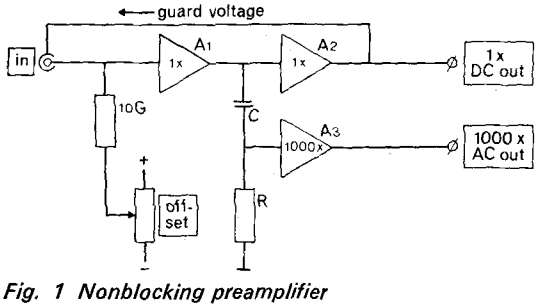

Fig. 1 Nonblocking preamplifier

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Thus, at the instant of making contact between the stimulus solution and the taste-hair tip, a voltage step V_2-V_1 occurs at the input of the preamplifier. To begin with, V_1 should be limited, for instance by incorporating an input resistor into the preamplifier. In this way the voltage step might be reduced to approximately 0·5 V.

The simplest circuit one can think of to achieve a short blocking time is a first-order RC highpass filter. Its time constant $\tau = R \times C$ has to meet two requirements. On the one hand, the baseline of the recording should be 'back on the oscilloscope screen' after 2 ms, i.e. within one spike amplitude (about 0·5 mV) of the original level. The step response has decreased to a thousandth after $6{\cdot}9\,\tau$, hence

$$6{\cdot}9\,\tau < 2 \text{ ms, so } \tau < 0{\cdot}29 \text{ ms} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

On the other hand, the filter should transmit the action potentials readily. The duration of these potentials is about 1·25 ms, which corresponds to a signal frequency band from 800 Hz upward. Therefore it is also required that the cutoff frequency

$$f_0 = 1/2\,\pi\tau < 800 \text{ Hz, so } \tau > 0{\cdot}20 \text{ ms} \quad . \quad . \quad . \quad (2)$$

The requirements of eqns. 1 and 2 can be met simultaneously, which implies that a sufficiently short blocking time can be achieved by means of a simple RC highpass filter, provided that a proper time constant is chosen.

The filter cannot be placed at the input of the preamplifier. In this case, R would consist of the input resistance of the preamplifier, e.g. 10 GΩ (MAES, 1977). This would require a coupling capacitor of about 0·02 pF, which is unrealisably small. Hence the filter has to be placed after the input stage, and this stage has to be able to transfer the entire voltage step without being overloaded and without too much distortion.

Design and performance of the preamplifier

The block diagram of the preamplifier is shown in Fig. 1. The input resistor of 10 GΩ is connected to an offset voltage source which is adjustable between +1 and −1 V. The impedance transformer A_1 consists of an f.e.t. source follower, fed by an f.e.t. current source. Its input bias current is of the order of 1 pA. A 1×d.c. output and the 'guard' voltage are obtained from the unity-gain buffer amplifier (emitter follower) A_2. The RC highpass filter has a time constant of 0·22 ms and is connected to a high-gain amplifier A_3.

Fig. 2 gives an example of the performance of the nonblocking preamplifier. In practice, the preamplifier reduces the blocking artefact to 2 ms for an input-voltage step not exceeding 100 mV. As the contact voltage V_2 does not change more than a few tens of millivolts for one and the same hair, and between hairs

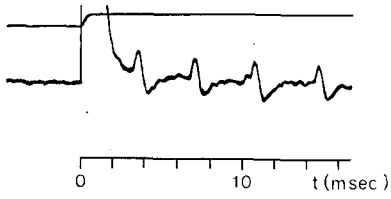

Fig. 2 Response of labellar taste hair of the blowfly calliphora vicina *to 1 M KCl, recorded with the nonblocking preamplifier. Upper trace, 1× d.c. output. A voltage step of 100 mV occurred at the onset of stimulation. Lower trace, 1000× a.c. output. The first spike of the salt receptor cell has a latency of about 3 ms*

during an experiment, the open voltage V_1 needs to be adjusted only once (using the offset knob) to achieve a sufficiently short blocking time during the entire experiment. This limits the input bias current of the preamplifier to about 10 pA, which is small enough to avoid electrical stimulation of the taste cells (MAES, 1977).

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F. W. MAES

Department of Zoology, Groningen State University, Kerklaan 30, Haren, The Netherlands.

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